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Understanding discourse-linked elements in aphasia: a threefold study in Russian

L.S. Bos [a,b,c], O. Dragoy [d,e], S. Avrutin [f], E. Iskra [d,g], & R. Bastiaanse [b,h]

[a]*International Doctorate for Experimental Approaches to Language and Brain (IDEALAB), Universities of Groningen (NL), Newcastle (UK), Potsdam (GE), Trento (IT) & Macquarie University, Sydney (AU), PO Box 716, 9700 AS Groningen, The Netherlands*
[b]*Center for Language and Cognition Groningen (CLCG), University of Groningen, PO Box 716, 9700 AS Groningen, The Netherlands*
[c]*University of Potsdam, Karl-Liebknecht-Str. 24-25, D-14476 Potsdam, Germany*
[d]*National Research University Higher School of Economics, Myasnitskaya st. 20, 101000 Moscow, Russia*
[e]*Moscow Research Institute of Psychiatry, Poteshnaya st. 3, 107076 Moscow, Russia*
[f]*Utrecht University, Trans 10, 3512JK Utrecht, The Netherlands*
[g]*Center for Speech Pathology and Neurorehabilitation, Nikoloyamskaya st. 20, 109240 Moscow, Russia*
[h]*University Medical Center Groningen (UMCG), PO Box 30001, 9700 RB Groningen, The Netherlands*

Corresponding author:
Laura S. Bos
Center for Language and Cognition Groningen (CLCG), University of Groningen
PO Box 716
9700 AS Groningen, The Netherlands
Phone: +31 50363 9396
Fax: +31 50 363 6855
E-mail: l.s.bos@rug.nl (L.S. Bos)

A B S T R A C T

Background: Agrammatic speakers have problems with grammatical encoding and decoding. However, not all syntactic processes are equally problematic: present time reference, *who* questions, and reflexives can be processed by narrow syntax alone and are relatively spared compared to past time reference, *which* questions, and personal pronouns, respectively. The latter need additional access to discourse and information structures to link to their referent outside the clause (Avrutin, 2006). Linguistic processing that requires discourse-linking is difficult for agrammatic individuals: verb morphology with reference to the past is more difficult than with reference to the present (Bastiaanse et al., 2011). The same holds for *which* questions compared to *who* questions and for pronouns compared to reflexives (Avrutin, 2006). These results have been reported independently for different populations in different languages. The current study, for the first time, tested all conditions within the same population.

Aims: We had two aims with the current study. Firstly, we wanted to investigate whether discourse-linking is the common denominator of the deficits in time reference, *wh* questions, and object pronouns. Secondly, we aimed to compare the comprehension of discourse-linked elements in people with agrammatic and fluent aphasia.

Methods and procedures: Three sentence-picture-matching tasks were administered to 10 agrammatic, 10 fluent aphasic, and 10 non-brain-damaged Russian speakers (NBDs): (1) the Test for Assessing Reference of Time (TART) for present imperfective (reference to present) and past perfective(reference to past), (2) the Wh Extraction Assessment Tool (WHEAT) for *which* and *who* subject questions, and (3) the Reflexive-Pronoun Test (RePro) for reflexive and pronominal reference.

Outcomes and results: NBDs scored at ceiling and significantly higher than the aphasic participants. We found an overall effect of discourse-linking in the TART and WHEAT for the agrammatic speakers, and in all three tests for the fluent speakers. Scores on the RePro were at ceiling.

Conclusions: The results are in line with the prediction that problems that individuals with agrammatic and fluent aphasia experience when comprehending sentences that contain verbs with past time reference, *which* question words and pronouns are caused by the fact that these elements involve discourse linking. The effect is not specific to agrammatism, although it may result from different underlying disorders in agrammatic and fluent aphasia.

Highlights

- time reference, *wh* questions, and personal pronouns were studied in Russian aphasia
- discourse-linked operations are impaired in individuals with aphasia
- a discourse-linking deficit is found in both agrammatic and fluent aphasia

Keywords: aphasia; sentence comprehension; discourse-linking; tense; time reference; *wh* questions; pronouns

1. Introduction

1.1 Discourse-linking theory and aphasia

Agrammatic aphasic individuals encounter problems with grammatical decoding. However, not all syntactic processing is equally problematic, which becomes apparent in studies that involve the relationship between different linguistic levels, specifically and most notably between narrow syntax and discourse structure. Processing at the level of narrow syntax activates the lexical and syntactic features of linguistic elements and involves computations over these elements. Discourse-linked elements have representation beyond the sentence boundaries, because they have a specific referent, or set of referents, that need to be identified. Pesetsky (1987) argues that for D(iscourse) linked elements a specific connection between their syntactic and discourse representation is required to ensure a correspondence between their grammatical function and eventual interpretation. In other words, processing such elements requires additional operations.

Taking as an example a difference between reflexive elements and pronouns, and also the difference between *Who* and *Which* questions, the following can be stated: For reflexives (e.g. *The woman$_i$ is washing [herself$_i$]*) and *who* questions (e.g. *Who is pushing the man?*) only narrow syntax is needed. The relation between a reflexive and its antecedent can be established within the sentence, by narrow syntax. Likewise, the question word *who* does not refer to a specific referent. However, for object pronouns (e.g. *The woman$_i$ is washing [her$_j$]*) and referential *which + NP* questions (e.g. *Which woman is pushing the man?*) discourse and access to information structure require additional processing apart from narrow syntactic-processing.

It has been shown that agrammatic speakers perform relatively well on sentences with reflexives and on *who* questions (see for example Avrutin, 2000, 2006, and the cited references therein). The scope of narrow syntax is only the sentence; hence, processing at the level of narrow syntax does not require much resource capacity. However, agrammatic speakers' performance on comprehending object pronouns and *which + NP* questions is often impaired. This is consistent with the so-called processing deficit account such as the one by Caplan, Waters, DeDe, Michaud, & Reddy (2007): Agrammatic individuals lack sufficient resources to successfully perform several syntactic operations simultaneously due to limited working-memory capacities.

Recently, the theory on impaired discourse-linking in agrammatic aphasia (Avrutin, 2006) has been combined with the idea from theoretical linguistics that past tense is discourse-linked (Zagona, 2003). Tense is a morphological inflection on the verb that provides information about the temporal relation, such as ‘simultaneity’ or ‘precedence,’ between the time interval of the event and the time of evaluation set by the context. Bastiaanse et al. (2011) expanded on Zagona’s and Avrutin’s theory and hypothesized that past time reference is discourse-linked, regardless of the tense

used.[1] Agrammatic speakers find it more difficult to produce and comprehend verb forms that refer to the past than verb forms that refer to the non-past, because of their difficulties with discourse linking, which is captured by the Past DIscourse LInking Hypothesis (PADILIH; Bastiaanse et al., 2011; Bastiaanse, 2013). The PADILIH predicts that verb forms with past time reference, such as 'wrote', are impaired in agrammatic aphasia, because they are discourse-linked: in order to interpret a verb with past time reference, a link has to be made to an event time. Also non-brain-damaged speakers (NBDs) require more resources to process past time reference than to process non-past time reference. Verb forms with non-past time reference,[2] such as 'writes', are relatively spared, because they can be processed by narrow syntax alone.

One of the issues in aphasiology is to what extent comprehension problems are specific to a particular syndrome. In non-brain-damaged people evidence for the linguistic complexity of past time reference comes from studies in which (discourse-related) electrophysiological differences in processing of past and non-past time reference violations have been found, which are related to discourse-processing (Dragoy, Stowe, Bos, & Bastiaanse, 2012) and not tense (Bos, Dragoy, Stowe, & Bastiaanse, 2013).

Also for people with fluent aphasia, discourse-linked past time reference requires additional processing. Production studies showed they could still refer to the past; however, they tend to resort to less complex verb forms with non-finite lexical verbs, such as 'has written.' Furthermore, agrammatic speakers are overall less consistent in assigning the correct time reference than fluent aphasic speakers (Dragoy & Bastiaanse, 2013; Bos & Bastiaanse, in press). Cho-Reyes and Thompson (2012) found that although syntactic abilities in fluent (anomic) aphasia are largely preserved, more complex forms of verbs and sentences are impaired. Processing of discourse-linked elements by fluent aphasic individuals in other domains has not been sufficiently addressed yet. Only a few studies with fluent aphasic participants reported on the performance in the domain of *who* and *which* questions (Wimmer, 2010) or in the pronominal domain (Love, Nicol, Swinney, Hickok, & Zurif, 1998; Ruigendijk & Avrutin, 2003; Grodzinsky, Wexler, Chien, Marakovitz, & Solomon, 1993) and no clear pattern emerged.

We investigated the processing of discourse-linked elements in both agrammatic and fluent aphasia in the domains of time reference, *wh* questions, and pronouns. In the following paragraphs, we review the literature on comprehension of discourse-linked elements in aphasia with a focus on these three domains. Subsequently, we provide the relevant linguistic background on Russian, the language under study, before describing the aims of our experiments.

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[1] For example, in English and Dutch one can refer to the past by using the present perfect: a verb form with an auxiliary in present tense that as a whole refers to the past. Such forms were also impaired compared to present time reference (Bos & Bastiaanse, in press).

[2] Aronson (1977), Partee (1973), and Zagona (2013) proposed that future tense should be seen as a sub-class of present tense. They assume it is derived from the present tense via modal and aspectual features. This view is adopted here by distinguishing between past and non-past time reference.

1.2 Previous studies on discourse-linked elements in aphasia

In studies on agrammatism, there is cross-linguistic evidence that supports and further refines the PADILIH. Bastiaanse et al. (2011) report data from the Test for Assessing Reference of Time (TART: Bastiaanse, Jonkers, & Thompson, 2008), which has a binary choice task for testing comprehension. In languages with a simple verb inflection paradigm (English) and more extensive verb inflection paradigms (Turkish) as well as in a language that uses freestanding grammatical morphemes for time reference (e.g. aspectual adverbs in Chinese), the pattern of reference to the past (through grammatical morphology) being more impaired than reference to the non-past emerged. The TART was also used to test an agrammatic aphasic group of Swahili-English bilinguals. They were more impaired in reference to the past than to the non-past in production and comprehension in both languages.

There are a number of grammaticality judgment studies in which the congruency of the temporal adverb and the verb's time reference was manipulated. No clear pattern has emerged from such studies. Stavrakaki and Kouvava (2003) reported near-ceiling performance for time reference violations by verbs with past time reference (expressed by past tense). Clahsen and Ali (2009) and Mészáros (2011) reported no difference between time reference violations by verbs with past time reference (expressed by past tense) and present time reference (expressed by present tense), and also the data from Greek agrammatism by Nanousi, Masterson, Druks, and Atkinson (2006) did not yield a particular pattern of time reference errors. Faroqi-Shah and Dickey (2009) found that agrammatic speakers of English responded faster to time reference violations by a verb with present time reference, than by a verb with past or future time reference, although the accuracy did not differ. These reaction time experiments seem to give more information than grammaticality judgment. However, if errors are made on such a task, it is unclear whether these are due to insufficient processing of the time reference of the verb, of the adverb, or of both. Thus, such studies are not very revealing concerning differences between time frames; they merely suggest that the time reference per se is problematic for an aphasic population.

Relatively few studies investigated time reference processing in fluent aphasia. In spontaneous speech of fluent aphasic speakers there are, to our knowledge, no reports of a marked deficit for past time reference, however, in an experimental setting, fluent aphasic speakers showed a quantitatively and qualitatively impaired performance on verbs with past reference compared to non-past reference (for production: Bos & Bastiaanse, in press; Dragoy and Bastiaanse, 2013; Kljajevic & Bastiaanse, 2011; Wieczorek, Huber, & Darkow, 2011; for production and comprehension: Jonkers & de Bruin, 2009). Two production studies with the TART have revealed that the problems with time reference do not surface similarly in agrammatic and fluent aphasic speakers, as reflected in an error analysis. Although the quantitative accuracy was the same in the two groups, agrammatic speakers were overall less consistent than fluent aphasic speakers in assigning temporal reference to verbs (Dragoy and Bastiaanse, 2013; Bos and Bastiaanse, in press). Jonkers and de Bruin (2009) investigated comprehension of time reference in a group of five

agrammatic speakers and seven speakers with Wernicke's aphasia in Dutch. Overall, past time reference (expressed by the simple past) was more difficult than non-past time reference (expressed by the simple present), with no difference for high or low frequency verbs.

Several studies have shown that *who* and *which* subject questions represent a similar dichotomy.[3] Hickok and Avrutin (1996) investigated processing of *wh* questions in two agrammatic speakers and found that comprehension of *which* subject questions was impaired, while comprehension of *who* subject questions was relatively spared. Similar results have been reported by Salis and Edwards (2008). Data from languages with a strong case system are also available, in which grammatical role assignment depends on the case (e.g. nominative and accusative case) of the noun phrase. Word order is less rigid. Neuhaus and Penke (2008) collected comprehension data from agrammatic speakers of German. With implicational scaling they show that *who* subject questions are better preserved than *which* subject questions.

However, other studies showed no difference between *who* and *which* questions, both being processed at ceiling in agrammatic aphasia. Stavrakaki and Kouvava (2003) had two agrammatic speakers of Modern Greek perform a grammaticality judgment task in which movement of *wh* operators was manipulated. Their participants scored at ceiling on *who* and *which* subject questions. Another study on in Modern Greek only focused on *who* questions about pictures, and also reported ceiling performance (Fyndanis, Varlokosta, & Tsapkini, 2010). Kljajevic and Murasugi (2010) investigated *who* and *which* questions in different structures in Croatian, a Slavic language. On an act-out task, most of their agrammatic participants performed at ceiling for direct questions, embedded questions, long-distance questions, and relative clauses, while for passive questions their performance contained considerable variation.

Little is known about *wh* extraction in fluent aphasia. Cho-Reyes and Thompson (2012) tested a large group of anomic aphasic individuals and found ceiling performance on *who* subject questions on a sentence-picture matching task. German fluent aphasic speakers tested by Wimmer (2010) comprehended *who* and *which* subject questions at chance level, with no significant difference between the two.

A number of experiments tested agrammatic individuals' comprehension of reflexives and pronouns by grammaticality judgment. Some studies report a difference between comprehension of reflexives and pronouns. Grodzinsky et al. (1993) used a picture verification task with sentences of the type: *Is Mama bear touching her/herself?* The authors interpret the results as chance performance for the English agrammatic speakers for the pronoun sentences where the picture did not

[3] Some studies also contained *wh* object questions. The difference between subject and object questions is out of scope of this paper.

match.[4] We reanalyzed their data to show that the mean accuracy of agrammatic speakers on sentences with reflexives was 90.2% and on pronouns was 63.5%. Ruigendijk, Vasić, and Avrutin (2006) tested Dutch agrammatic speakers with a ternary choice picture-sentence matching task. The individuals with aphasia performed significantly worse than the non-brain-damaged participants on pronouns, but not on reflexives. In a follow-up experiment they compared pronouns and reflexives in Exceptional Case Marking constructions of this kind: *...en daarna zag de man$_i$ zichzelf$_{i/*j}$ / hem$_{*i/j}$ voetballen*: 'and then the man$_i$ saw himself$_{i/*j}$ / him$_{*i/j}$ play soccer'. Here, the performance on pronouns was significantly worse than the performance on reflexives.

Other studies have not reported any difference between comprehension of reflexives and object pronouns. Edwards and Varlokosta (2007) performed an experiment with English agrammatic speakers similar to the one by Grodzinsky et al. (1993) and report overall chance performance on mismatch conditions. They conclude that in agrammatic comprehension both reflexives and pronouns are impaired, but on the basis of their experiment they cannot tell whether this is due to the same underlying disorder. Martínez Ferreiro (2010) used a binary choice sentence-picture matching test to investigate comprehension of object versus reflexive clitics in agrammatic speakers of Ibero-Romance languages. Overall performance was at ceiling, without significant differences between conditions.

Love et al. (1998) conducted an online priming paradigm experiment in which the activation of the referent of either a pronoun or a reflexive was measured. Sentences were of the type *The boxer$_i$ said that the skier$_j$ in the hospital had blamed him$_i$/himself$_j$ for the recent injury*. At the point of *him/himself*, priming of the subject-NP of the embedded sentence (*skier*) was investigated. The healthy control group correctly showed a priming effect for *skier* at *himself*, and not at *him*. However, the three individuals with Broca's aphasia showed no priming for *skier* at *himself,* and incorrect priming for *skier* at *him*. Hence, not only did the reflexive not yield a priming effect for its referent *skier*, but also the pronoun incorrectly elicited activation for the *skier*. This study suggests that the processing of both pronouns and reflexives is impaired in agrammatism.

Fewer studies investigated pronominal and reflexive reference in fluent aphasia. Data from a sentence-picture matching task in Dutch with two fluent aphasic participants suggested a general problem with referential elements (Ruigendijk & Avrutin, 2003). Grodzinsky et al. (1993) administered their picture verification task to a group of individuals with Wernicke's aphasia, who scored at chance level for

[4] We investigated the possibility that the agrammatic and fluent aphasic participants in Grodzinsky et al.'s study had a yes bias, which may lead to a better score for the pronoun sentences where the picture matched. We reanalyzed their data with A', a technique to take out a bias in yes/no-answers (Grier, 1971). The conclusion that Grodzinsky et al. (1993) drew, that the fluent and agrammatic aphasic groups show a very different performance pattern can be refined: in their study, both aphasic groups performed worse on pronoun conditions as compared to reflexive conditions (Wilcoxon's test: $W = 95$, $p < .002$), but their error patterns are different, because the agrammatic speakers exhibited a yes-bias.

matching and non-matching pronoun conditions. Our reanalysis of these data confirmed that the fluent aphasic individuals understood reflexives (96.9% accuracy) better than pronouns (69.7% accuracy). The priming effect study by Love et al. (1998) also included English-speaking participants with Wernicke's aphasia. These participants behaved similarly to healthy participants: at the reflexive, they showed correct priming of the corresponding antecedent, which was absent when a pronoun was encountered.

In sum, there is cross-linguistic evidence that in agrammatic and fluent aphasia, reference to the past is more vulnerable than reference to the non-past in languages that obligatorily mark time reference on the verb (see Bastiaanse, 2013, for a more extensive review). Verbs demanding discourse-linking require more grammatical computation than verbs that can be processed without discourse-linking. Studies that reported a significant difference between *who* and *which* in agrammatic aphasia, point to an impairment of the latter (Hickok & Avrutin, 1996; Salis & Edwards, 2008; Neuhaus & Penke, 2008), but not all studies found divergent behavior on these structures (Stavrakaki & Kouvava, 2003; Kljajevic & Murasugi, 2010). For fluent aphasic speakers no asymmetric comprehension pattern of *wh* extracted questions emerged (Wimmer, 2010). Regarding aphasic comprehension of reflexives and object pronouns, no clear pattern has emerged. Some studies on agrammatic aphasia reported worse comprehension of object pronouns than reflexives (Grodzinsky et al., 1993; Ruigendijk, Vasić, & Avrutin, 2006; Love et al., 1998), although in other studies both types of anaphora were impaired (Edwards & Varlokosta, 2007) or spared (Martínez Ferreiro, 2010). Previous research on fluent aphasia does not unequivocally point towards impaired processing of pronouns compared to reflexives either (no impairment: Love et al., 1998; overall impairment: Ruigendijk & Avrutin, 2003; pronouns processing worse than reflexives: Grodzinsky et al., 1993).

1.3 Linguistic background of Russian

In Russian, time reference is conveyed through verb inflections for tense and is closely related to a verb's aspect. A distinction is made between past, present and future verb forms, and each verb falls into one of two aspectual categories: perfective or imperfective. There is no unique way to form one aspectual form from another, although some rules can be applied. Aspectual counterparts of a verb are therefore assumed to be different lexical entries and have different lemmas in the dictionary. There is a particular correspondence between time reference and aspect in Russian: simple perfective verb forms may refer to the past or the future, while simple imperfective verb forms refer to the past or present. For past reference, the verbs receive a suffix *–l-* and gender and number marking on the verb stem, for example, past imperfective *pisa-l*: 'he was writing', and past perfective *napisa-l*: 'he wrote'. The present imperfective is formed with number and case marking on the verb stem, for example, *pish-et*: 's/he is writing'. Future perfective requires the same inflection as present imperfective, but added to a perfective verb stem: *napish-et*: 's/he will write'. For a more extensive background on the Russian tense/aspect system, see

Dragoy and Bastiaanse (2013). Based on their Russian production data by agrammatic and fluent aphasic speakers, the authors argue that in Russian the prototypical form for past time reference is the past perfective; that is, perfective aspect prototypically denotes completed, past events. Imperfective aspect primarily refers to ongoing, non-past events. The prototypical form for non-past time reference is, therefore, the present imperfective. Comprehension of these prototypical forms will be studied in the current time reference experiment.

For the *wh* experiment, we used the unmarked word order for *wh*-subject questions. The basic word order of Russian is Subject-Verb-Object (SVO), although the major sentence constituents can be put in any order when it is pragmatically adequate (Bailyn, 1995). *Wh*-subject question words are in nominative case, and *which* question words are gender marked: *kto*: 'who', and *kakoj/kakaja*: 'which'. Thematic role assignment relies on morphology rather than on the specific syntactic positions: compare, e.g., *kakoj muzhchina presledujet zhenschinu*: 'which-NOM man-NOM chases woman-ACC' and *zhenschinu presledujet kakoj muzhchina*: 'woman-ACC chases which-NOM man-NOM', both translated as 'which man is chasing the woman'.

Reflexive reference is expressed in Russian as the *-s'a* particle (suffix) on the verb, which is not inflected for gender, number or case: *myt'-s'a*: 'wash himself/herself'. Pronominal reference, however, is made with a separate personal pronoun, which is gender-, number- and case-marked: *jego*: 'him', and *jejo*: 'her'; e.g., *myt' jego/jejo*: 'wash him/her'.

1.4 Goals of the study

The theory of discourse-linking (Pesetsky, 1987) applies to different domains. If there is an overall impairment of discourse-linking in agrammatic aphasia, as hypothesized by Avrutin (2000, 2006), and if past time reference is indeed discourse-linked, as stated in the PADILIH, then discourse-linking should the common denominator of the deficits in time reference, *wh* questions, and object pronouns. Until now, this has not been investigated within the same population. Our first goal is to systematically investigate the influence of discourse-linking in these three linguistic domains.

We have previously shown that discourse-linking negatively affects fluent aphasic production on the TART (Dragoy & Bastiaanse, 2013; Bos & Bastiaanse, in press). In parallel, we expect that the additional processing in discourse syntax that is necessary for discourse-linking will increase the error rate in fluent aphasic comprehension. Our second goal is to compare comprehension of discourse-linked elements in two different aphasic populations: agrammatic and fluent.

2. Materials and methods

2.1 Participants

There were three participant groups: 10 NBDs, 10 individuals suffering from non-fluent agrammatic aphasia (A1 to A10) and 10 individuals suffering from fluent aphasia (F1 to F10). A certified clinical psychologist diagnosed the aphasic

participants using Luria's Neuropsychological Investigation (Luria, 1966) at the Center for Speech Pathology and Neurorehabilitation, Moscow. The agrammatic participants had efferent aphasia (roughly equivalent with Broca's aphasia) and/or dynamic aphasia (a disruption in converting internal speech into spoken utterances; to some degree similar to transcortical motor aphasia), in some cases accompanied by afferent aphasia (roughly equaling apraxia of speech). In the subtests of the neuropsychological investigation targeting sentence construction and spontaneous speech, all participants belonging to this group were diagnosed as agrammatic (effortful, non-fluent speech with errors in inflection, omission of function words combined with relatively good auditory comprehension). They demonstrated effortful, telegraphic, non-fluent speech with relative intact comprehension. The fluent aphasic speakers all had sensory aphasia (roughly corresponding to Wernicke's aphasia), which was in some cases accompanied by acoustic-mnestic aphasia (with the main deficit expressed as anomia and problems with retention of acoustic verbal traces). Their speech output was fluent with word-finding difficulties, verbal and phonemic paraphasias, and their comprehension was impaired.

All brain-damaged participants were aphasic due to a single left-hemisphere stroke except for A5 and F8, who suffered traumatic brain injury, and A3, A6, and F5, who suffered a second stroke. All participants were right-handed and had normal or corrected-to-normal vision, and no hearing problems. Russian was their native language. The mean age of the NBDs was 43.9 (range: 22-74, SD = 15.7), of the agrammatic speakers 43.5 (range: 35-66, SD = 9.7), and of the fluent speakers 55.2 (range 22-68, SD = 13.1). A one-way ANOVA shows no significant difference in age between the three groups ($F(2,29) = 2.60$, $p = .09$). In Appendix 1, the individual participant characteristics are given.

2.2 Materials

To investigate the discourse-linked and locally-bound elements conveying time reference, *wh* reference and pronominal reference, three subtests with similarities in their design were administered to the participants. The order of the items within the test was pseudo-randomized so that no more than three subsequent trials where of the same condition and target gender. Position of the target was balanced across conditions.

For comprehension of time reference, the *Test for Assessing Reference of Time (*TART: Bastiaanse, Jonkers & Thompson, 2008; see Bastiaanse et al., 2011, for more background on this test) was employed. The TART comprehension subtest used in the current study consisted of 20 transitive action verbs in two conditions, so 40 items in total.[5] Each item contained a simple verb form: the past perfective (prototypical form for past time reference in Russian), and the present imperfective (prototypical form

[5] The TART contained a third condition (with 20 items) for a different research question on prototypicality in time reference (see Dragoy & Bastiaanse, 2013). This condition was the Future Perfect. We will report on the results in a later paper.

for present time reference in Russian). Every sentence consisted of three words: the subject (man or woman), the verb and the object, for example *muzhchina rv'ot bumagu*: (lit. man-NOM tears paper-ACC) 'the man is tearing paper' and *muzhchina porval bumagu* (lit. man-NOM tore paper-ACC): 'the man tore paper'. A complete list of the verbs used in the test is given in Appendix 2. Interpretation of the time reference relied on the verb's aspect and its tense morphology. The comprehension TART is a binary choice task. Two color photographs were available per verb, one showing the action being finished and one showing it going on. The two photos were presented above each other. An example of an item is given in Figure 1 at the left.

Figure 1. Examples of test items. Left: an example of the TART (*target: muzhchina rv'ot bumagu* (lit. man-NOM tears paper-ACC): 'the man is tearing paper'). Middle: an example of the WHEAT (*target: kto nes'ot zhenschinu* (lit. who-NOM carries woman-ACC): 'who is carrying the woman?'). Right: an example of the RePro (*target*: *zhenschina katajets'a* (lit. woman-NOM karts-REFL): 'the woman karts herself').

For comprehension of *wh* questions, a test was developed in analogy with the TART: the WH Extraction Assessment Test (WHEAT). This test investigated subject questions with *who* and *which*. The WHEAT consisted of 20 verbs used in two conditions, 40 items in total.[6] The two types of *wh* phrases were in nominative case: *kto*: 'who-NOM', and *kakoj muzhchina/kakaja zhenschina*: 'which man/which woman-NOM'. Every sentence consisted of three constituents: the *wh* phrase, the verb and an object noun (man or woman), for example, *kto nes'ot muzhchinu?* (lit. 'who-NOM carries the man-ACC?'): 'who is carrying the man?' and *kakoj muzhchina*

[6] The WHEAT contained two more conditions (with 20 items each) for a different research question on the difference between subject and object *wh* questions (as for example reported in Hickok & Avrutin, 1996). This research question is out of scope of the current paper.

nes'ot zhenschinu? (lit. 'which man-NOM carries the woman-ACC?'): 'which woman is carrying the man?' A complete list of the verbs is given in Appendix 2. The *wh* phrases referred to a single person. Therefore, the participant was asked to point to one particular person in the two contrasting color pictures. Four models were used to create two picture-pairs: one showed the action being performed by a man to a woman, and one showed the action being performed by another woman to another man. The person performing the action was always on the left side. An example of an item is given in Figure 1 in the middle.

For comprehension of pronominal reference, a test was developed in analogy with the TART and WHEAT: the Test for Reflexives and Pronouns (RePro). The RePro consisted of 20 verbs used twice (once with male and once with female actors) in two conditions (reflexive and pronoun), so 80 items in total. The verbs could all be used as a reflexive verb, with the reflexive suffix *–s'a*, and with an object pronoun (*jego*: 'him', or *jejo*: 'her'). Every sentence consisted of two or three words: the subject (man or woman), the verb (with the reflexive suffix for the reflexive condition) and the object pronoun, for example *zhenschina katajets'a*: (lit. woman-NOM karts-REFL): 'the woman karts herself' or *zhenschina katajet jejo*: (lit. woman-NOM karts her-ACC): 'the woman karts her'. A complete list of the verbs is given in Appendix 2. In the RePro, participants had to choose between two contrasting color photographs: one showing the action being performed to another person of the same gender, and one showing the action being performed to the acting person himself/herself, where a second person appeared passively in the picture. The acting person was always on the left side, and the passive person on the right. An example of an item is given in Figure 1 at the right.

2.3 Procedure

For the three tests, the experimenter showed a pair of two pictures to the participant and read a sentence aloud. The participant was asked to point to the photograph (in case of the *wh* questions the person) matching the sentence. The TART began with two practice items with the verbs 'to read' and 'to write', which were repeated until the participant understood the task: *muzhchina chitaet pis'mo* (lit. man-NOM reads letter-ACC): 'the man is reading the letter', and *muzhchina napisal pis'mo* (lit. man-NOM wrote letter-ACC): 'the man wrote the letter'. For the WHEAT, the practice items contained the verbs 'to massage' and 'to feed': *kto massazhirujet zhenschinu?* (lit. who-NOM massages the woman-ACC?): 'who is massaging the woman?' *kakaja zhenschina kormit muzhchinu?* (lit. which woman-NOM feeds man-ACC?): 'which woman is feeding the man?' The participant was asked to point to a particular person in the photo. For the RePro, there were four practice items that contained the verb 'to shave' for the male actors and 'to make up' for the female actors: *muzhchina brejet ego* (lit. man-NOM shaves him-ACC): 'the man is shaving him' and *zhenschina krasits'a* (lit. woman-NOM makes-up-REFL): 'the woman is making herself up'. When the participant pointed to the wrong picture, the sentence matching that picture was contrasted with the probe sentence. On experimental items, no feedback was given. Responses were scored as correct when the participant pointed to the target picture. If the participant asked for more than one repetition, the

response was counted as incorrect. The TART was always administered first, and the WHEAT was always administered last.

2.4 Data analysis

To test for an overall reliable difference between NBDs and the two aphasic groups, a linear mixed-effects regression analysis was carried out using the *lmer* function of the *lme4* package (Bates, Maechler, & Bolker, 2013) and Tukey's contrasts from the *glht* function of the *multcomp* package (Hothorn et al., 2013) in R (R Core Team, 2013). The dependent variable of the model was log-linked accuracy (1=correct, 0= incorrect) with random effect factors for Participant and Item. A separate model was developed to investigate differences between conditions and aphasic groups. This model contained the fixed effects Aphasia type (agrammatic / fluent), Test (TART / WHEAT / RePro), Discourse-linking (yes / no) with a three-way interaction and the fixed effect Trial number. There were random-effect factors for Participant and Item with random slopes for Trial number, Test and Discourse-linking per Participant, and a random slope for Discourse-linking per Item. The model was developed by excluding insignificant parameters from a full model containing Aphasia type, Test, Discourse-linking, and Trial number with interactions between them as fixed factors. There were also interactions between Trial number, Test and Discourse-linking per Participant as random slopes and Discourse-linking by Item as random slope. Model comparison was based on the Akaike Information Criterion (AIC) and log likelihood ratio tests (significance defined as $p < .05$).

3. Results

In Figure 2, the mean accuracy on the three tests is given for the two aphasic groups. Individual scores can be found in Appendix 3.

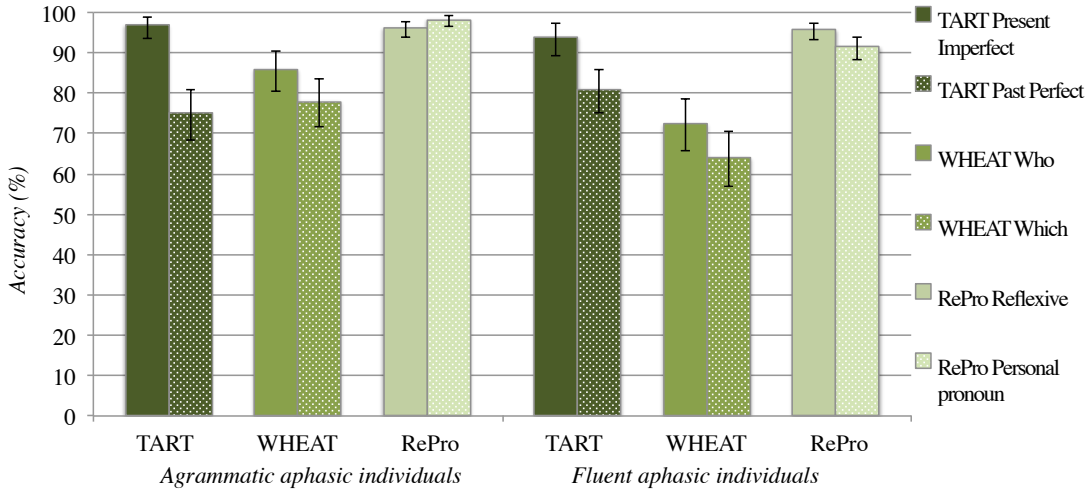

Figure 2. Accuracy per subtest for the agrammatic and fluent aphasic speakers. Note that the dashed bars denote discourse-linked conditions.

The NBDs scored at ceiling; no errors were made on any test. The accuracy of the agrammatic and fluent aphasic speakers was significantly lower than the accuracy of the NBDs ($\beta = -6.30$, $SE = 1.19$, $z = -5.31$ and $\beta = -6.97$, $SE = 1.18$, $z = -5.88$,

respectively). The data of NBDs will be further ignored. The fluent and agrammatic speakers' overall accuracy did not differ (β = 0. 67, *SE*= 0.34, *z* = 1.98).

There was a three-way interaction between the factors of Aphasia group, Test, and Discourse-linking (model with a three-way interaction versus a model without an interaction with a) Aphasia type: χ^2 (5) = 24.30, $p < .001$, with b) Test: χ^2 (6) = 29.91, $p < .001$, and with c) Discourse-linking: χ^2 (5) = 26.93, $p < .001$). In order to interpret this interaction, the data were broken down along the variable of Aphasia type, while keeping the remaining model the same and with both models including the variables of Test and Discourse-linking.

In the analysis of agrammatic speakers, there was an interaction between the variables Test and Discourse-linking (model with a two-way interaction versus a model without an interaction: χ^2 (2) = 5.17, $p > .05$, with a lower AIC for the model including the interaction). In order to interpret this interaction, the three tests were analyzed separately.[7] On the TART, agrammatic individuals scored significantly lower on the discourse-linked past perfective than on the non-discourse-linked present imperfective (β = -3.02, *SE*= .64, *z* = -4.69). On the WHEAT, agrammatic speakers scored significantly lower on the discourse-linked *which* condition than on the non-discourse-linked *who* condition (β = -1.88, *SE*= .83, *z* = -2.29). On the RePro, there was no significant discourse-linking effect (model with versus model without the fixed factor of Discourse-linking: χ^2 (1) = 0.004, $p > .05$, with a lower AIC for the model without Discourse-linking), explaining the two-way interaction. This can also be seen in Figure 2: discourse-linking played no significant role in the agrammatic speakers' accuracy on the RePro, where scores were at ceiling.

For the fluent aphasic speakers, there was no significant interaction between Test and Discourse-linking (model with a two-way interaction versus a model without an interaction: χ^2 (2) = 2.00, $p > .05$, with a lower AIC for the model without the interaction). Tukey's contrast showed that the three tests differed significantly from one another, with the highest accuracy on the RePro and the lowest accuracy on the WHEAT (TART vs. RePro β = -1.43 *SE*= 0.40, *z* = -3.60, WHEAT vs. RePro β = -3.00 *SE*= 0.57, *z* = -5.22). Furthermore, on all three tests discourse-linked conditions were more difficult than non-discourse-linked conditions (model with versus model without the fixed factor Discourse-linking χ^2 (1) = 6.23, $p < .05$). This explains the three-way interaction in the model combining both aphasia types.[8]

[7] During the instruction of the WHEAT, agrammatic aphasic participant A3 was still not able to point to the target referent after several repetitions of the practice items. We continued with the experimental items because we hoped she would start understanding the test. We included her data in the final analyses, however, an analysis without her data of the WHEAT did not yield different results.

[8] We performed the accuracy analysis in a sample of participants with stroke-induced aphasia only (9 agrammatic aphasic participants and 9 fluent aphasic participants) and the results were identical to the analysis in which the TBI patients were included. Including age as a predictor did not change the results either.

4. Discussion

With the current study we aimed to investigate whether the problems with *which* questions, past time reference and pronominal reference are caused by the same underlying disorder, that is, a problem with processing discourse-linked elements. Second, we compared comprehension of discourse-linked elements in agrammatic and fluent aphasic speakers.

Our first prediction, that discourse-linking is impaired in the three investigated domains, was supported by the tests outcomes. In the domain of time reference, the TART showed that past was more impaired than present in both aphasic groups, in line with previous studies (Abuom & Bastiaanse, 2013; Bastiaanse, 2008; Bastiaanse et al., 2011; Dragoy and Bastiaanse, 2013, Faroqi-Shah & Dickey, 2009; Jonkers & de Bruin, 2009; Nanousi et al., 2006; Stavrakaki & Kouvava, 2003, but no difference was found in grammaticality judgments in Stavrakaki & Kouvava, 2003; Clahsen & Ali, 2009; Mészáros, 2011; Nanousi et al., 2006). In the domain of *wh*-subject questions, the WHEAT revealed that *which* questions were more difficult than *who* questions, which aligns with previous results by Hickok and Avrutin (1996), Neuhaus and Penke (2008), and Salis and Edwards (2008), but no such difference was found by Stavrakaki and Kouvava (2003) and Kljajevic and Murasugi (2010). The RePro, however, only revealed a discourse-linking effect in the fluent aphasic group and was not sufficiently sensitive to demonstrate what problems the agrammatic participants experience in the pronominal domain. Previous studies have not shown a clear pattern in this domain either. Some studies showed impaired comprehension of pronouns and relatively intact comprehension of reflexives (i.e., the bias-corrected scores of Grodzinsky et al., 1993; the incorrect priming of pronouns versus the null-effect on reflexives in agrammatic individuals in Love et al., 1998; the Dutch agrammatic individuals in Ruigendijk, Vasić, and Avrutin, 2006). However, other studies showed impaired comprehension overall (in agrammatic aphasia: Edwards & Varlokosta, 2007; in fluent aphasia: Ruigendijk & Avrutin, 2003).

The results support the idea of Avrutin (2000, 2006) that comprehension of discourse-linked elements is impaired in agrammatic aphasia. It requires extra grammatical processing, which is more demanding for the system compared to processing structures that involve only narrow syntax operations. As computational load increases, errors do so as well, according to processing accounts such as the one by Caplan et al. (2007). More errors are made when the sentence is more complex, because processing by discourse syntax breaks down, and the difference between non-discourse-linked and discourse-linked conditions on a certain test become proportionally larger.

Our second aim was to compare agrammatic and fluent aphasic comprehension of discourse-linked elements. Our results show that also in fluent aphasia, comprehension of discourse-linked elements causes difficulties, as demonstrated by the results of the TART, WHEAT, and RePro. Jonkers and de Bruin (2009) reported similar results in the domain of time reference for agrammatic and fluent aphasia. In the domain of *wh*-subject questions, a previous comprehension study showed no influence of discourse-linking for fluent aphasic participants, but

chance level performance in both *which* subject questions and *who* subject questions (Wimmer, 2010).

In the pronominal domain, the results of agrammatic and fluent aphasic speakers differ. The interaction we found in the overall analysis pointed to a lacking effect of discourse-linking in the agrammatic aphasic speakers, although we did find statistical evidence for such an effect in the fluent aphasic group. Closer inspection of the data shows, however, that both aphasic participant groups scored near ceiling on this test. As in agrammatic aphasia, previous research on fluent aphasia does not unequivocally point to impaired processing of pronouns compared to reflexives (no impairment: Love et al., 1998; overall impairment: Ruigendijk & Avrutin, 2003; pronoun impairment: Grodzinsky et al., 1993). The combined evidence of our current study and previous studies makes it difficult to draw a conclusion with regards to the influence of discourse-linking on pronominal reference.

The PADILIH (Bastiaanse et al., 2011) was originally based on data from agrammatic aphasia. We found support for a distinction between non-past and past time reference in NBDs as well (Dragoy et al., 2012; Bos et al., 2013). Our current results have implications for this hypothesis, too. In agrammatic aphasia, past time reference difficulties are a central deficit, affecting both production and comprehension (Bastiaanse et al., 2011). Jonkers and de Bruin (2009) reported problems with comprehension of past time reference compared to non-past time reference in Dutch agrammatic and fluent aphasic individuals. Previous experiments show that also in fluent aphasic production, verb forms that require discourse-linking, that is, verb forms referring to the past, cause more difficulties than verb forms for which no such linking is needed; that is, verb forms referring to the present (Bos & Bastiaanse, in press; Dragoy & Bastiaanse, 2013; Kljajevic & Bastiaanse, 2011; Wieczorek, Huber, & Darkow, 2011). Hence, the past time reference deficit is central in both types of aphasia, extending the scope of the PADILIH to fluent aphasia.

The patterns of impairment are similar in the agrammatic and fluent aphasic group. However, that does not mean that the underlying disorder is the same. Earlier research has shown that fluent aphasic individuals often show a similar qualitative performance, but the underlying deficit can nonetheless differ from that of agrammatic aphasic individuals (Balogh & Grodzinsky, 2000; Bastiaanse & Edwards, 2004; Bastiaanse, 2011). Analysis of production errors on verb morphology for time reference showed that agrammatic aphasic speakers more often switch to another time frame than fluent aphasic speakers (Dragoy & Bastiaanse, 2013; Bos & Bastiaanse, in press). We believe other methods should be used to investigate whether the problems with comprehension of discourse-linked elements stem from different underlying disorder in agrammatic and fluent aphasia. We are currently performing an eye-tracking experiment that can potentially illuminate this issue.

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References

Abuom, T. & Bastiaanse, R. (2013). Production and comprehension of reference of time in Swahili–English bilingual agrammatic speakers, *Aphasiology, 27*, 157-177.

Aronson, H. (1977). The interrelationships between aspect and mood in Bulgarian. *Folia Slavica, 11*, 9–32.

Avrutin, S. (2000). Comprehension of discourse-linked and non-discourse-linked questions by children and Broca's aphasics. In Y. Grodzinsky, L.P. Shapiro & D. Swinney (Eds.), *Language and the brain: Representation and processing.* (pp. 295–313). San Diego, CA: Academic Press.

Avrutin, S. (2006). Weak syntax. In Y. Grodzinsky & K. Amunts (Eds.), *Broca's region* (pp. 49–62). Oxford: Oxford University Press.

Bailyn, J. (1995). *A configurational approach to Russian ''free'' word order*. Doctoral Dissertation, Cornell University, Ithaca, NY.

Balogh, J. & Grodzinsky, Y. (2000). Levels of linguistic representation in Broca's aphasia: Implicitness and referentiality of arguments R. Bastiaanse & Y. Grodzinsky (Eds.) *Grammatical disorders in aphasia: A neurolinguistic perspective.* (pp 88-14). London: Whurr Publishers.

Bastiaanse, R. (2008). Production of verbs in base position by Dutch agrammatic speakers: Inflection versus finiteness. *Journal of Neurolinguistics, 21*, 104–119.

Bastiaanse, R. (2011). The retrieval and inflection of verbs in the spontaneous speech of fluent aphasic speakers. *Journal of Neurolinguistics, 24*, 163–172.

Bastiaanse, R. (2013). Why reference to the past is difficult for agrammatic speakers. *Clinical Linguistics and Phonetics, 27*, 244-63.

Bastiaanse, R., Bamyaci, E., Hsu, C., Lee, J., Yarbay Duman, T., & Thompson, C. K. (2011). Time reference in agrammatic aphasia: A cross-linguistic study. *Journal of Neurolinguistics, 24*, 652–673.

Bastiaanse, R., & Edwards, S. (2004) Word order and finiteness in Dutch and English Broca's and Wernicke's aphasia. *Brain and Language, 89*, 91-107.

Bastiaanse, R., Jonkers, R., & Thompson, C. K. (2008). *Test for Assessing Reference of Time (TART)*. Groningen: University of Groningen.

Bates, D., Maechler, M. & Bolker, B. (2013). *Linear mixed-effects models using S4 classes*. R Foundation for Statistical Computing, Vienna, Austria. URL http://lme4.r-forge.r-project.org/

Bos, L.S., & Bastiaanse, R. (in press). Time reference decoupled from tense in agrammatic and fluent aphasia. *Aphasiology*, DOI: 10.1080/02687038.2014.886322.

Bos, L.S., Dragoy, O., Stowe, L.A. & Bastiaanse, R. (2013). Time reference teased apart from tense: Thinking beyond the present. *Journal of Neurolinguistics, 2*, 283–297. DOI: 10.1016/j.jneuroling.2012.10.001.

Caplan, D., Waters, G., DeDe, G., Michaud, J., & Reddy, A. (2007). A study of syntactic processing in aphasia I: Behavioral (psycholinguistic) aspects. *Brain and Language, 101*, 103–150.

Clahsen, H., & Ali, M. (2009). Formal features in aphasia: Tense, agreement, and mood in English agrammatism. *Journal of Neurolinguistics, 22*, 436-451.

Cho-Reyes, S. & Thompson, C.K. (2012). Verb and sentence production and comprehension in aphasia: Northwestern Assessment of Verbs and Sentences (NAVS). *Aphasiology, 26*, 1250–1277.

Dragoy, O. & Bastiaanse, R. (2013). Aspects of time: Time reference and aspect production in Russian aphasic speakers. *Journal of Neurolinguistics, 26*, 113–128.

Dragoy, O., Stowe, L.A., Bos, L.S., & Bastiaanse, R. (2012). From time to time: Processing time reference violations in Dutch. *Journal of Memory and Language, 66,* 307–325.

Edwards, S., & Varlokosta, S. (2007). Pronominal and anaphoric reference in agrammatism. *Journal of Neurolinguistics, 20*, 423-444.

Faroqi-Shah, Y., & Dickey, M.W. (2009). On-line processing of tense and temporality in agrammatic aphasia. *Brain and Language, 108,* 97–111.

Fyndanis, V., Varlokosta, S., & Tsapkini, K. (2010). Exploring wh-questions in agrammatism: Evidence from Greek. *Journal of Neurolinguistics, 23*, 644-662.

Grier, J. B. (1971). Nonparametric indexes for sensitivity and bias: Computing formulas. *Psychological Bulletin, 75*, 424-429.

Grodzinsky, Y., Wexler, K., Chien, Y., Marakovitz, S., & Solomon, J. (1993). The breakdown of binding relations. *Brain and Language, 45*, 396-422.

Hickok, G. & Avrutin, S. (1996). Comprehension of wh-questions in two Broca's aphasics. *Brain and Language, 52,* 314–327.

Hothorn, T., Bretz, F., Westfall, P., Heiberger, R.M., & Schuetzenmeister, A. (2013). *Simultaneous inference in general parametric models.* R Foundation for Statistical Computing, Vienna, Austria. URL http://lme4.r-forge.r-project.org/

Jonkers, R., & de Bruin, A. (2009). Tense processing in Broca's and Wernicke's aphasia. *Aphasiology, 23*, 1252-1265.

Kljajevic, V. and Bastiaanse, R. (2011). Time reference in fluent aphasia: Evidence from Serbian. In A. Vatakis, A. Esposito, M. Giagkou, F. Cummins, and G. Papadelis (Eds.) *Multidisciplinary aspects of time and time perception*, number 6789 in Lecture Notes in Artificial Intelligence, pages 258–274, Heidelberg etc., 2011. COSTS TD0904 International Workshop, Springer.

Kljajevic, V. & Murasugi, K. (2010). The role of morphology in the comprehension of wh-dependencies in Croatian aphasic speakers. *Aphasiology, 24*, 1354-1376.

Love, T., Nicol, J., Swinney, D., Hickok, G., & Zurif, E. (1998). The nature of aberrant understanding and processing of pro-forms by brain-damaged populations. *Brain and Language, 65*, 59-62.

Luria, A. R. (1966). *Higher cortical functions in man.* New York: Basic Books.

Nanousi, V., Masterson, J., Druks, J., & Atkinson, M. (2006). Interpretable vs. uninterpretable features : Evidence from six Greek-speaking agrammatic patients. *Journal of Neurolinguistics, 19*, 209–238.

Neuhaus, E., & Penke, M. (2008). Production and comprehension of wh-questions in German Broca's aphasia. *Journal of Neurolinguistics, 21*, 150–176.

Martinez-Ferreiro, S. (2010). *Towards a Characterization of Agrammatism in Ibero-Romance.* Doctoral thesis, Autonomous University of Barcelona, Spain. http://filcat.uab.cat/clt/publicacions/tesis/pdf/Martinez.pdf.

Mészáros, É. (2011). Selective tense deficit in Hungarian agrammatic aphasia. *Acta Linguistica Hungarica, 58*, 39-64.

Partee, B. H. (1973). Some structural analogies between tenses and pronouns in English. *The Journal of Philosophy, 70,* 601–609.

Pesetsky, D. (1987). Wh-in-Situ: Movement and Unselective Binding. In E. J. Reuland, & A. G. B. ter Meulen (Eds.), *The representation of (in)definiteness* (pp. 98-129). Cambridge, MA: MIT Press.

R Core Team (2013). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Ruigendijk, E., & Avrutin, S. (2003). The comprehension of pronouns and reflexives in agrammatic and Wernicke's aphasia. *Brain and Language, 87*, 17–18.

Ruigendijk, E., Vasić, N., & Avrutin, S. (2006). Reference assignment: Using language breakdown to choose between theoretical approaches. *Brain and Language, 96*, 302-317.

Salis, C. & Edwards, S. (2008). Comprehension of wh-questions and declarative sentences in agrammatic aphasia: The set partition hypothesis. *Journal of Neurolinguistics, 21*, 375–399

Stavrakaki, S., & Kouvava, S. (2003). Functional categories in agrammatism: Evidence from Greek. *Brain and Language, 86*, 129–141.

Wieczorek, R., Huber, W., & Darkow, R. (2011). Tense/aspect category in fluent and nonfluent German aphasia: An experimental training programme for verb production. *Aphasiology, 25,* 851–875.

Wimmer, Eva (2010). *Die syntaktischen Fähigkeiten von Wernicke-Aphasikern - eine experimentelle Studie*. Doctoral Dissertation, Universität Düsseldorf, Germany. http://docserv.uni-duesseldorf.de/servlets/DocumentServlet?id=16808.

Zagona, K. (2003). Tense and anaphora: Is there a tense-specific theory of co-reference? In A. Barrs, (Ed.), *Anaphora: A reference guide.* (pp. 140–171). Oxford: Blackwell Publishing.

Zagona, K. (2013). Tense, aspect and modality. In M. den Dikken, (Ed.) *The Cambridge handbook of generative syntax.* (pp. 746–792). Cambridge: Cambridge University Press.

Bos, L.S., Dragoy, O., Avrutin, S., Iskra, E., & Bastiaanse, R. (2014). Understanding discourse-linked elements in aphasia: a threefold study in Russian. *Neuropsychologia.*

Appendix 1. Individual participants characteristics.

Pp	Sex	Age	Education	Aphasia type	Time PO	Etiology	Location of lesion	Hemi-plegia
Agrammatic aphasic participants								
A1	f	43	higher	efferent / mild dynamic, medium	5y	hCVA	left temporo-parietal	right
A2	m	35	higher	efferent (Broca), medium	4m	hCVA	arteriovenous malformations left temporo-parietal	right
A3	f	46	higher	efferent (Broca)	2y / 5m	CVA	left middle cerebral artery	right
A4	f	36	higher	dynamic	2y	iCVA	left middle cerebral artery thrombosis, post-stroke changes in left frontoparietal-temporal region	right
A5	f	38	secondary	efferent, medium	2y	TBI	subarachnoid - parenchymal left	no
A6	m	66	secondary	mild efferent	1y / 4m	CVA	left middle cerebral artery	right
A7	f	37	higher	mild efferent	5y4m	CVA	left middle cerebral artery	right
A8	m	53	secondary	efferent, dynamic	1y9m	CVA (mixed)	origin in the left middle cerebral artery	no
A9	m	44	secondary	afferent, efferent	8m	CVA	cortico-subcortical left frontal, parietal and temporal	no
A10	f	37	secondary	dynamic, efferent, afferent	2y10m	CVA after aneurysm	anterior and middle cerebral arteries	right
Fluent aphasic participants								
F1	f	57	secondary	sensory / acoustic-mnestic	2y3m	CVA	left middle cerebral artery	no
F2	f	68	higher	sensory	4.5m	iCVA	left parietal region, with impregnation	no
F3	m	55	higher	sensory	7y2m	CVA	left middle cerebral artery	no
F4	m	59	higher	sensory	3m	iCVA	left temporo-occipital region	no
F5	f	58	higher	sensory	1y10m / 2y2m	subarachnoid hCVA / intra-cerebral hematoma	right temporal lobe, 4.5 months later aneurysm clipping left hemisphere	no
F6	m	65	secondary	severe sensory	7m	iCVA	left internal carotid artery, vascular-alcoholic genesis	no
F7	m	48	secondary	medium / severe sensory, acoustic-mnestic	3m	CVA	left middle cerebral artery	no
F8	m	22	incomplete higher	medium-severe sensory / acoustic-mnestic	2y4m	TBI	intracerebral hematoma of the left parietal region, midline shift of the brain	no
F9	m	65	higher	sensory / acoustic-mnest	4y6m	CVA	left parietal / signs of lacunar strokes basal ganglia right	no
F10	f	55	higher	sensory	1y2m	hCVA	post-hemorrhagic cyst left temporo-parietal-occipital	no
Non-brain-damaged participants								
C1	f	28	higher					
C2	f	48	higher					
C3	f	53	higher					
C4	m	22	incomplete higher					
C5	f	49	higher					
C6	f	74	secondary					
C7	m	47	higher					
C8	f	55	higher					
C9	f	31	higher					
C10	m	32	higher					

Pp = participant; Time PO = Time post-onset; y= years; m= months; hCVA = hemorrhagic cerebrovascular accident; iCVA = ischemic cerebrovascular accident; TBI = traumatic brain injury.

Appendix 2. Verbs used in the test (plus object nouns of TART).

TART				**RePro**		**WHEAT**	
Russian verb	Russian noun	Translated verb	Translated noun	Russian verb	Translated verb	Russian verb	Translated verb
vymyt'	pol	to mop	floor	vzveshivat'	to weigh	vzveshivat'	to weigh
podmesti	pol	to sweep	floor	vytirat'	to dry	vytirat'	to dry
vypit'	moloko	to drink	milk	katat'	to kart	gladit'	to stroke
nalit'	moloko	to stir	milk	kachat'	to swing	nakryvat'	to cover
napolnit'	papku	to fill	folder	myt'	to soap	nesti	to carry
osvobodit'	papku	to empty	folder	nakryvat'	to cover	obuvat'	to put-shoes-on
narisovat'	kvadrat	to paint	square	oblivat'	to splash on	odevat'	to dress
nachertit'	kvadrat	to draw	square	obuvat'	to put-shoes-on	ostanavlivat'	to stop
pogladit'	sviter	to iron	sweater	odevat'	to dress	podnimat'	to lift
slozhit'	sviter	to fold	sweater	osvobozhdat'	to free	presledovat'	to chase
podt'anut'	telezhku	to pull	kart	podnimat'	to walk up	priv'azyvat'	to tie
tolknut'	telezhku	to push	kart	podstrigat'	to cut	pr'atat'	to hide
porvat'	bumagu	to tear	paper	prist'ogivat'	to fasten	razgl'adyvat'	to investigate
prikleit'	bumagu	to glue	paper	pr'atat'	to hide	razdevat'	to undress
potochit'	karandash	to sharpen	pencil	razdevat'	to undress	raschesyvat'	to comb
slomat'	karandash	to break	pencil	raschesyvat'	to comb	tolkat'	to push
pochistit'	jabloko	to peel	apple	spuskat'	to walk down	fotografirovat'	to photograph
s'est'	jabloko	to eat	apple	umyvat'	to wash	zelovat'	to kiss
sv'azat'	koftu	to knit	shirt	fotografirovat'	to photograph	schekotat'	to tickle
sshit'	koftu	to sew	shirt	chistit'	to brush	schipat'	to pinch

Appendix 3. Individual aphasic participant accuracy, calculated over 20 items per condition for the TART and WHEAT, and 40 items for the RePro. The non-brain-damaged control participants did not make any errors.

	TART		**RePro**		**WHEAT**	
	PastPerf (%)	**PresImp (%)**	**Pro (%)**	**Refl (%)**	**Who (%)**	**Which (%)**
A1	70.0	100.0	92.5	87.5	80.0	60.0
A2	85.0	100.0	100.0	100.0	100.0	100.0
A3	70.0	95.0	100.0	100.0	40.0	85.0
A4	85.0	100.0	100.0	100.0	95.0	85.0
A5	85.0	100.0	97.5	100.0	100.0	95.0
A6	55.0	90.0	95.0	80.0	55.0	40.0
A7	95.0	100.0	100.0	100.0	90.0	60.0
A8	45.0	90.0	100.0	100.0	100.0	90.0
A9	90.0	100.0	100.0	97.5	100.0	100.0
A10	70.0	95.0	97.5	97.5	100.0	65.0
Mean	*75.0*	*97.0*	*98.3*	*96.3*	*86.0*	*78.0*
F1	75.0	100.0	100.0	95.0	100.0	95.0
F2	75.0	90.0	85.0	92.5	35.0	60.0
F3	85.0	100.0	97.5	97.5	80.0	85.0
F4	95.0	100.0	95.0	100.0	35.0	10.0
F5	50.0	95.0	82.5	90.0	70.0	55.0
F6	60.0	65.0	57.5	85.0	50.0	60.0
F7	95.0	95.0	97.5	97.5	100.0	60.0
F8	95.0	100.0	100.0	100.0	100.0	85.0
F9	85.0	95.0	100.0	100.0	90.0	90.0
F10	95.0	100.0	100.0	100.0	65.0	40.0
Mean	*81.0*	*94.0*	*91.5*	*95.8*	*72.5*	*64.0*